National Bureau of Standards

TECHNICAL NEWS BULLETIN

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Fire-Retardant Coatings for Aircraft

As the result of a joint research program between the National Bureau of Standards and the Civil Aeronautics Administration, coatings have been developed for fabric-covered aircraft that approximately double the time interval between ignition of the fabric and its destruction by fire. These findings, based on both laboratory and wind-tunnel burning tests [1] conducted by S. G. Weissberg, H. L. Hansberry, and G. M. Kline, provide a basis for more effective extinguishment of fires in flight, particularly those arising from power plants in small craft.

Safety in aircraft has been a subject of numerous investigations over a period of many years. However, it has for some time been evident that it is useless, especially in small planes, to provide elaborate means for detection or extinguishment of a fire if the fabric control surfaces burn away before the equipment can be set in operation.

The highly flammable cellulose-nitrate dope used on airplane fabrics has been responsible for much loss of life and property by fire. Although dopes based on other cellulose derivatives—such as ethyl cellulose, cellulose acetate, and cellulose acetate butyrate—are much more difficult to ignite and have a much lower flame velocity, even they are unsatisfactory in a power-plant fire, in which flame from burning gasoline or oil may be in continuous contact with doped fabric for several seconds. Yet no fire-retardant film-forming materials are known that tauten airplane fabrics as effectively and as permanently as do the dopes based on the cellulose derivatives. Unfortunately, the addition of resins or other fire-retardant substances to these compounds lessens their capacity to tauten. Efforts were therefore directed toward the development of highly efficient fire-retardant coatings to be applied to the surface after it is already doped. In designing the coatings, the peculiar requirements of aircraft use made it necessary to consider not only fire-retardant effectiveness but also aerodynamic smoothness, adhesion, flexibility, effect on tautness of the substrate dope, application characteristics, durability, and resistance to gasoline, oil, and ethylene glycol.

The materials that have been used most successfully in fire-retardant coatings for other purposes include film-forming substances and pigments, which in burning give off large quantities of noncombustible gases; substances that exclude oxygen by forming an impenetrable protective glaze; and compounds that absorb the heat of the flame through endothermic changes. Typical of the film-forming plastic materials studied were chlorinated rubber, chlorinated neoprene, chlorinated polyisoprene, vinyl chloride-acetate, vinylidene chloride-acrylonitrile, and vinylidene chloride-vinyl chloride. Among the modifying resins were alkyd and phenolic resins, urea-formaldehyde, chlorinated paraffin, and chlorinated diphenyl. Pigments investigated included antimony oxide, calcium carbonate, magnesium ammonium phosphate, titanium dioxide, and zinc borate. In addition, several commercial preparations

1 For further technical details, see Fire-retardant coatings for fabric-covered aircraft, by S. G. Weissberg, H. L. Hansberry, and G. M. Kline, Ind. and Eng. Chem. 41, 1742 (1949).

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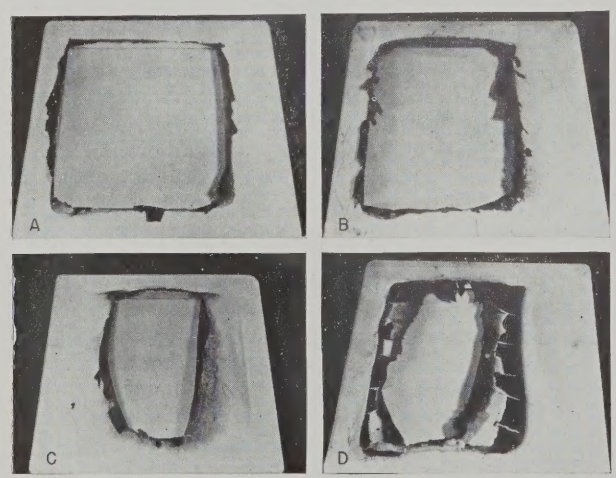
recommended by manufacturers as flame-resistant coatings were evaluated for comparative purposes.

The burning and weathering tests were conducted on fabric panels that had been prepared according to Navy specifications by applying four coats of clear and two coats of white-pigmented cellulose acetate butyrate dope to 4-ounce airplane fabric. Over this substrate, from one to four coats of the fire-retardant coatings were applied.

Two laboratory methods for evaluation of burning characteristics were employed. The "still-air" burning test involved simply the measurement of the time required for a flame front to move a definite distance along a horizontally supported test fabric. Later, as better coatings were developed, this test proved inadequate to differentiate among the better, self extinguishing coatings; apparatus was therefore designed for a more rigorous "moving-air" burning test. In this method, a small centrifugal fan drew air through a funnel-shaped entrance port consisting in part of a doped-fabric test panel attached to the lower side of the funnel. The fire-retardant coating was applied to the upper surface of the panel, and a Meker burner, adjusted to give a quiet blue flame 9 inches high, was placed in the air stream so that the flame lay flat on the coated surface. In addition to measurement of the time interval between the instant of flame contact and the ignition of the dope, the time elapsing between flame contact and the charring of the underside of the fabric was also recorded. As the air velocity measured by a small hot-wire anemometer at the center of the entrance port was only 6.5 miles per hour, the flow was laminar, and the test conditions were highly reproducible; the standard deviation of an individual measurement calculated from 119 pairs of duplicate measurements was about 1 second.



Fire-retardant coatings for fabric-covered aircraft developed at the Bureau effectively double the time interval between ignition of the fabric and its destruction by fire. (A) Panel treated with cellulose nitrate dope only; destruction time, 2 seconds; (B) cellulose nitrate dope plus fire-retardant mixture, 4 seconds; (C) cellulose acetate butyrate dope, 6 seconds; (D) cellulose acetate butyrate dope plus the same fire-retardant mixture, 12 seconds.

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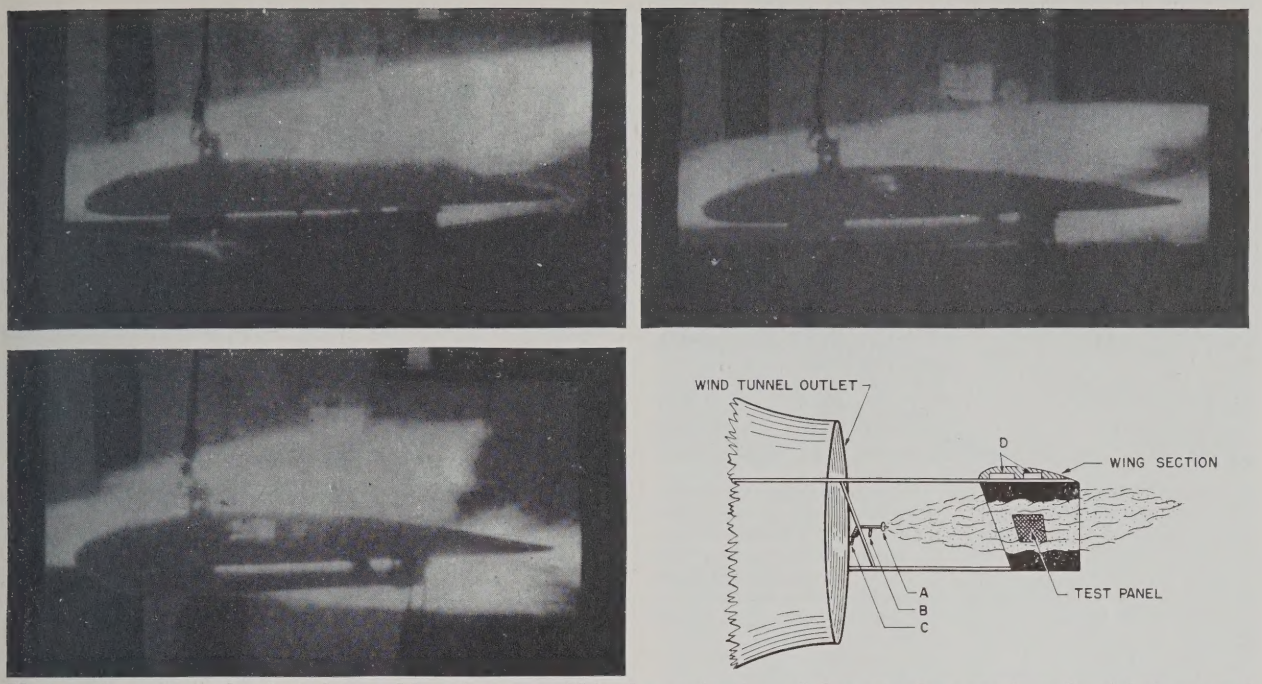
On the basis of the laboratory evaluation of the fire-retardant properties of a large number of coatings, 15 of the more promising coating systems were selected for full-scale wind-tunnel tests. A steel wing section was suspended at the outlet of an open-type wind-tunnel operated to provide a 70-mile-per-hour air stream. Test panels, prepared by applying from one to four coats of fire-retardant lacquer to fabric doped with the usual six coats of cellulose acetate butyrate, were placed in an opening 12 inches square in the center of the lower surface of the wing and parallel to the axis of the wind tunnel. A spray gun mounted immediately forward of the wing served to introduce a uniform spray of 90-octane aviation gasoline into the air stream. At "zero" time, the spray was ignited by a spark from a high-tension aircraft spark plug. This enveloped the wing section in burning gasoline, insuring continuous contact of the specimen with flame during the entire test.

The course of the fire was recorded by a motion picture camera. The camera was also aimed at a mirror placed within the wing section to permit observation of the inside surface of the test panel. Observers provided with stop watches noted the time for the destruction of the outer coating and the time of fabric failure; an auxiliary time scale was provided by a large sweep-second electric clock placed in the field of view of the camera. Temperatures were recorded at points within and just outside of the fabric by means of thermocouples and rapid-response recording pyrometers.



Motion-picture records of wind-tunnel burning tests aid in the evaluation of fire-retardant coatings for fabric-covered aircraft. A steel wing section, containing a test panel of coated fabric, is suspended at the outlet of an open-type wind tunnel. A uniform spray of gasoline, ignited by a high-tension spark plug (A, lower right) envelopes the wing section with a continuous flame. The camera, aimed through the openings at D (seen as light patches, upper right and lower left), records the charring of the inner surface of the test panel, by means of a mirror placed within the wing section. Observers on the outside note the time for destruction of the outer coating and the time of fabric failure.

The evidence presented by the wind-tunnel tests showed clearly that it is possible to increase the time for fabric destruction from the 6 seconds characteristic of cellulose acetate butyrate to about 12 seconds. Some additional improvement can be achieved by designing the outer coating to have greater mechanical strength after burning so that it will not be blown away so easily by the wind stream.

Although very few of the fire-retardant coatings that were developed in this investigation have the flexibility and durability of the cellulose acetate butyrate dope, several of them are of sufficient utility to merit further development. The film-forming bases that gave the best results all have considerable organically combined chlorine, which on pyrolysis gives off appreciable quantities of hydrochloric acid gas. Pigments such as zinc borate and antimony oxide were also quite effective in increasing the production of noncombustible gas. Magnesium ammonium phosphate, on the other hand, is too water-soluble for outdoor use. Antimony oxide and calcium carbonate in combination appeared to be superior to antimony oxide alone. The maximum pigment content compatible with flexibility and weathering requirements was about 40 percent of the solids. Although fire-retardancy is increased for higher pigment contents, such over-pigmented coatings are not sufficiently durable.

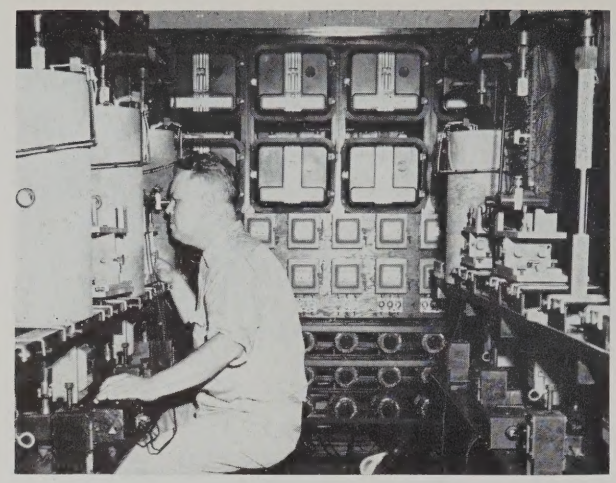
High-Strength Ceramics for High-Temperature Use

Results of recent tests at the National Bureau of Standards have shown that several ceramic bodies previously developed by the Bureau have marked superiority, in both strength and creep characteristics at 1,800° F. and above, over the best available high-temperature metal alloys. Laboratory data indicate that these ceramic bodies, especially designed for use in jet engines and gas turbines, possess special properties required at the elevated operating temperatures of these power plants.[2]

[2] For further technical details, see Strength and creep characteristics of ceramic bodies at elevated temperatures, by M. D. Burdick, R. E. Moreland, and R. F. Geller, NACA Technical Note No. 1561, available from the National Advisory Committee for Aeronautics, Washington 25, D. C.

The revolutionary developments during the past 30 years, particularly the last 10, in both design and efficiency of power plants have emphasized the need for materials of great strength and durability at very high temperatures. This is a natural consequence of the fact that, in any device for the conversion of heat energy into work, the efficiency of that device may be increased by increasing the temperature differential between the beginning and end of the conversion.

Because design engineers projected their plans into regions of temperature and stress far beyond the potentialities of known metallic alloys, a survey of nonmetallic compounds, especially the oxides, silicates,



The mechanical properties of high-temperature ceramics are determined at elevated temperatures in specially designed electric furnaces. The amount of elongation, or creep, is indicated by gages attached to the specimen and read by means of a microscope. Stress is applied through ceramic adapters (specimen assembly, with furnace removed, extreme right, and closeup, opposite page) and a lever system from below the furnace.

carbides, and related combinations peculiar to ceramics became necessary. Little data existed in the literature upon which to base specific designs for the application of ceramics in power plants such as the gas turbine. Some work had been done on feldspathic bodies, which contain a bond of glass and, consequently, have limited use at elevated temperatures. Several reports were also available in the German literature on small specimens of simple oxide bodies with extraordinary resistance to mechanical stress at temperatures above 1,800° F. These had been matured, experimentally, at such high temperatures (about 3,450° to 3,550° F.) that their successful production commercially in the United States seemed to be only a remote possibility.

Therefore, when the National Bureau of Standards was requested, by the National Advisory Committee for Aeronautics in 1944, to obtain engineering data on ceramic bodies in tension at elevated temperatures, it was thought advisable to begin the work on materials that could be produced with available industrial facilities. Leading ceramic producers were requested to submit specimens for preliminary tests of bending at elevated temperatures and of resistance to thermal shock. Also, six promising compositions were selected from a number developed at the National Bureau of Standards during a previous investigation. These tests, involving bending strength at 1,800° F. and relative resistance to thermal shock, showed the oxide bodies developed at the Bureau to have superior quality over commercial products then available. A comprehensive investigation was begun on the high-temperature strength and creep in pure tension of six NBS oxide bodies.

For test purposes specimens round in cross section and approximately 0.3 inch in diameter throughout the gage length were prepared. The adapters for applying the stress were $8\frac{1}{2}$ inches long, $1\frac{3}{16}$ inches in diameter, and were made of one of the ceramic bodies under test. Ceramic adapters were used because calculations based on the data available indicated that high-temperature alloys would not have sufficient strength at the maximum temperatures and stresses likely to be obtained in some of the tests. Both adapters and test specimens were fabricated under contract by a cooperating manufacturer, using hydrostatic pressure applied by means of rubber molds. The strain gages, similar in design to those used at the Bureau for measuring creep of metals, were fabricated from 90-percent platinum, 10-percent rhodium tubing and wire.

Four thermocouples mounted in the vicinity of the specimen provided temperature measurements at the ends and at the center of the gage length and actuated the temperature controlling and recording instruments. The specimens were heated in conventional wire-wound furnaces equipped with viewing windows to permit the periodic measurement of strain using a Gaertner extensometer-viewing microscope. Loads were applied to the specimen through a lever system.

Four general methods of test were followed, the first two of which may be described as "step testing."

Method 1.—The specimen was heated gradually to the test temperature, and a stress considered to be well below the tensile strength of the specimen was applied. After observing length changes for some predetermined time, the stress was increased. Length changes were observed again, whereupon another increment of stress was applied. This was repeated until rupture occurred. It was customary to increase the stress in increments of 1,000 lb/in.^{2} at about 1-week intervals.

Method 2.—The original temperature and load conditions were essentially as described for method 1. In this method, however, the load remained constant and the temperature was raised, usually in 100-degree F steps at about 1-week intervals. In some cases, the specimen had not ruptured after prolonged heating at 1,800° F. When this occurred in a furnace in which the temperature could not be raised safely above 1,800° F, the test was continued by increasing the load in steps while maintaining the 1,800° F temperature.

Method 3.—After holding the specimen at 1,800° F under a stress of 4,000 lb/in.^{2} for 48 hours, stress was increased at the rate of about 1,200 lb/in.^{2} per minute to failure. The load was increased by flowing shot into a bucket.

Method 4.—The specimen was held at constant stress and constant temperature to failure, the purpose being to obtain curves of stress against rupture time, which could be compared with similar curves for metal alloys.

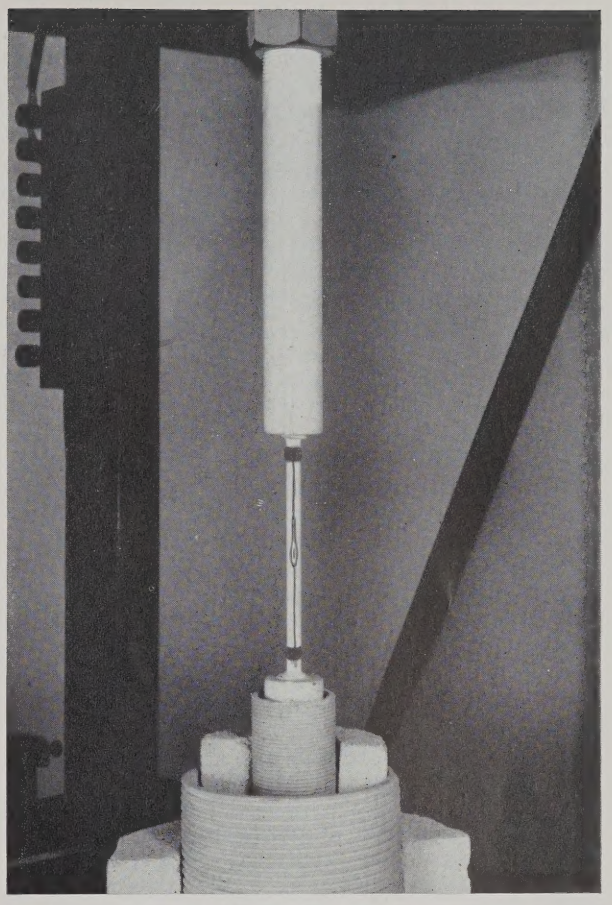
In general, each combination of stress and temperature was maintained for about 160 hours, or 1 week. Conditions were then changed by an increment of either stress or temperature, until failure, for a total of 109 tests. Strengths in tension up to 18,000 lb/in.^{2} at 1,800° F, and 15,000 lb/in.^{2} at 1,900° F, were observed. Above 1,900° F, however, the strengths drop off rapidly to an average of about 5,000 lb/in.^{2} at 2,000° to 2,200° F.

Resistance to creep also decreases rapidly, for the particular porcelains tested, when temperatures are raised above the range 1,800° to 1,900° F. Results show that even the comparatively low stress of 6,000 lb/in.^{2} has caused more than a 10-fold increase in the rate of creep at 2,050° F compared to the rate at 1,800° F—and the porcelains on which these tests were made are the most resistant to creep of any investigated. Maximum observed creep rates, for all of the bodies tested, may be summarized as ranging from about 0.0001 to 0.0002 percent per hour at 1,700° F for the range of stresses used; from 0.0002 to 0.0008 percent per hour at 1,800° F and a stress of 16,000 lb/in.^{2}; and, from 0.0030 to 0.0040 percent per hour at 1,900° F and 10,000 lb/in.^{2} stress. The maximum stress at rupture for the four NBS ceramic bodies at various temperatures is given in the accompanying table.

Stress-temperature data on four high-strength ceramic bodies

Temperature	Maximum stress			
	NBS ceramic bodies			
	#358	#353	#151	#4811C
°F	*lb./in.*^{2}	*lb./in.*^{2}	*lb./in.*^{2}	*lb./in.*^{2}
1,500	13,000	13,000	12,000	14,000
1,700	14,000	13,000	13,000	14,000
1,800	17,000	18,000	18,000	18,000
1,900	8,000	4,000	15,000	16,000
2,100	------	------	------	6,000

Data obtained from the Bureau's tests have revealed that some of the NBS oxide bodies are capable of effectively withstanding high-temperature conditions far better than any other material now in use. In fact, an experimental gas turbine, using blades fabricated from the oxide body of the most promising strength and creep characteristics, has been operated successfully in the Cleveland Laboratory of the NACA.



Specimens of special ceramics for high-temperature applications (reduced diameter with gage attached) are screwed into ceramic adapters, through which stress is applied for the creep test. The adapters are fabricated from one of the experimental ceramics.

Atomic Energy Levels

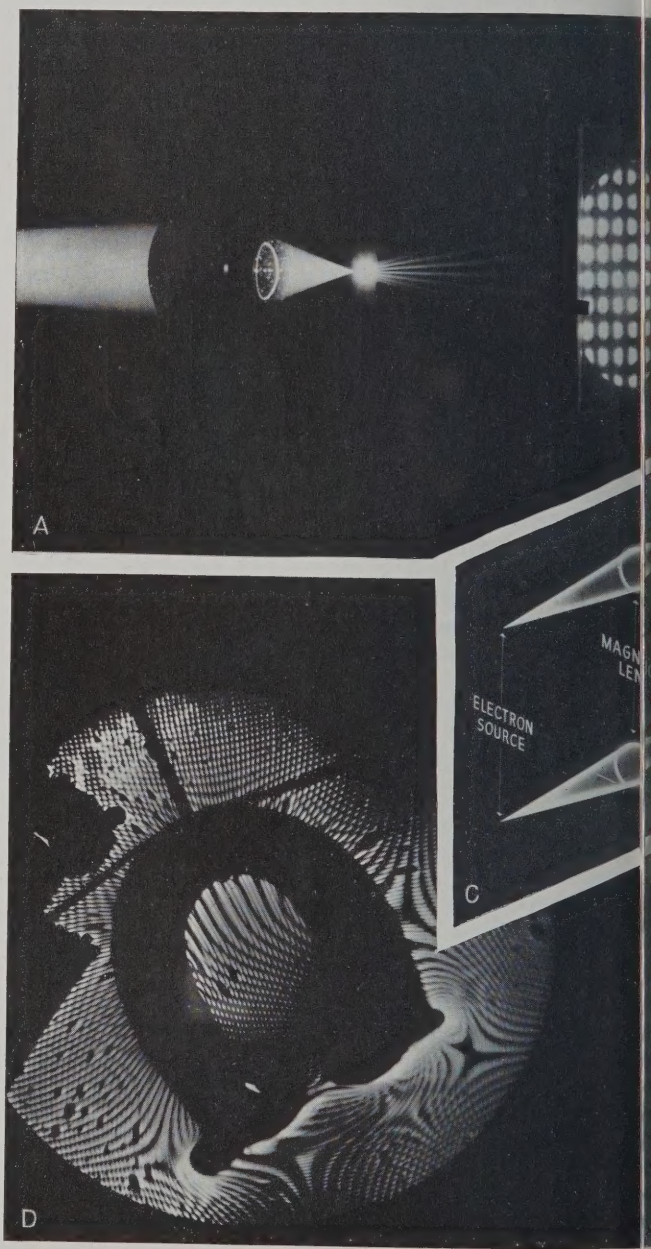
A compilation of all known data on the energy levels of elements of atomic number 1 through 23 (hydrogen through vanadium) has been published by the National Bureau of Standards. Designed to meet the needs of workers in nuclear and atomic physics, astrophysics, and chemistry, this publication is an up-to-date compendium of all energy levels for these elements. The new series represents the cooperative efforts of scientists throughout the world and constitutes the first compilation of atomic energy levels in 18 years, during which time the number of known energy levels has increased four or five times.

In this series, spectra are presented in order of increasing atomic number, and under a given atomic number they are listed in order of increasing stages of ionization. For each spectrum a selected bibliography covering the analysis is given. The energy levels are tabulated in the related groups that form spectroscopic terms, counting upward from the lowest as zero. Electron configurations are also given in the tables, together with term intervals, Landé g-values, and term designations in a uniform notation. For the more complex spectra, arrays of observed terms and their electron configurations are included. Similar arrays of the terms predicted by theory for important isoelectronic sequences are given in the introduction.

Volume 1 (containing Sections 1 to 3) of NBS Circular C467, *Atomic Energy Levels*, by Charlotte E. Moore, contains 352 large 2-column pages and is cloth-bound. It can be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of $2.75 a copy. Remittances from foreign countries must include one-third the publication price to cover mailing costs.

Electron-Opti

An electron-optical shadow technique developed at the trostatic and magnetic fields of extremely small dimensi experiment in light optics (A and B). (A) A mounte reduced image of the source at a point ahead of a wire s formed (right) by projection from the reduced image. plastic (left) deformed along its edge in such a way corresponding part of the shadow network on the screen. replaced by a magnetic lens, which converges an electron b between the electron source and the magnetic lens (thin broadening of the crossover and a corresponding distortio shadow of a fine wire mesh is distorted by the deflection about ¼ inch wide. (E) Superposed on the image of a beyond the back focus of an electron lens. From the d the absolute value of the magnetic field intensity at a cor



As the result of a series of electron-microscope experiments at the National Bureau of Standards, Dr. L. L. Marton of the Bureau's electron physics laboratory has developed an electron-optical shadow technique [3] that provides a valuable tool for the quantitative study of electrostatic and magnetic fields of extremely small dimensions. The new method makes use of an electron lens system to produce a shadow image of a fine wire mesh placed in the path of the electron beam. From the distortion in the shadow network caused by deflection of the electrons as they pass through the field under study, accurate values of field strength are computed. Thus it is possible to investigate quantitatively fields that have not been susceptible to other methods of investigation, for example, the fringe fields from the small domains of spontaneous magnetization in ferromagnetic materials.

The new development, which is based on extensive theoretical analysis, should provide a powerful means for broadening present knowledge concerning space-charge fields, fields produced by contact potentials, patch fields in thermionic emission, charge distribution in a gaseous plasma, waveguide problems, and the basic magnetic properties of metals. Though similar in some respects to the electron-optical Schlieren method [4] previously developed at the Bureau, the shadow method is much better adapted to precise determinations of field intensity.

Principle

The principle of the shadow method was discovered in the course of a study of a recording wire magnetized in evenly spaced short pulses by means of a conventional magnetic recording head. In practice, the recording wire—or other object to be studied—is placed between an electron source and a system of electron lenses. The lens system focuses the electron beam to form an image of the wire on a fluorescent screen. By placing a wire mesh of known gage just beyond the back focus of the lens system, a shadow image of the mesh is superposed on the image of the wire. This shadow image is formed by projection from the virtual source provided by the reduced image of the source of electrons. The portions of the shadow network adjacent on the screen to magnetized regions of the recording wire are then found to show considerable distortion.

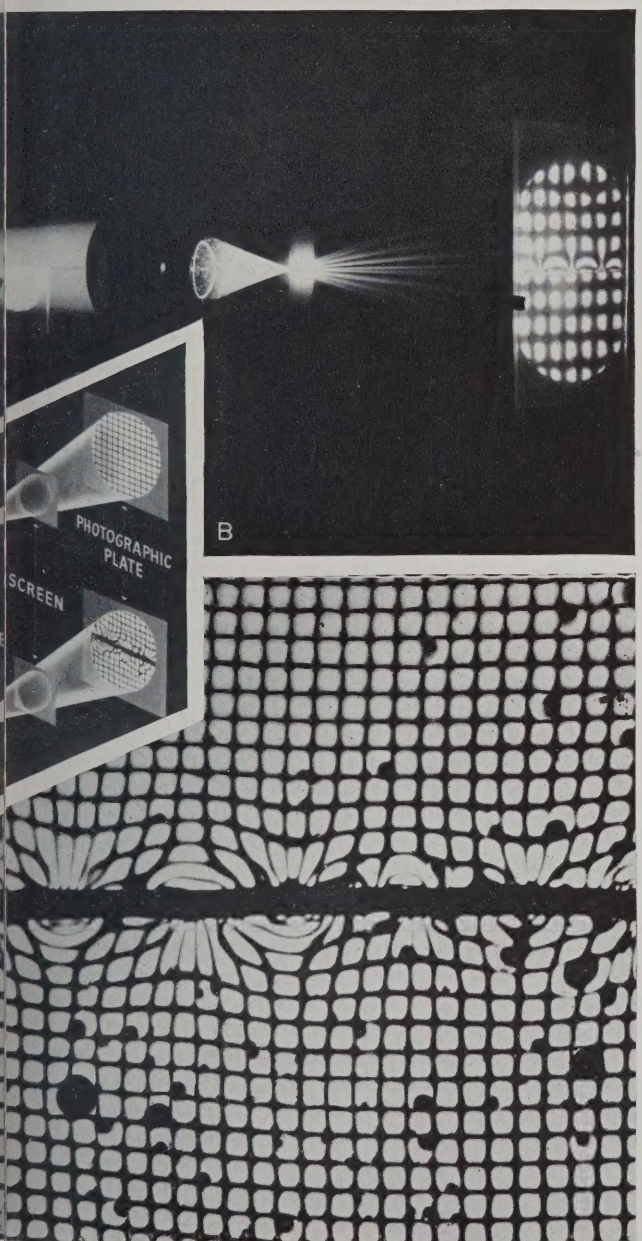
A complete theoretical analysis of this effect has shown that the distortion of the shadow image is due to the deflection of the electron beam by the field of the recording wire at each magnetized region. The result is a corresponding displacement of the reduced image

[3] For further technical details, see Electron optical observation of magnetic fields, by L. Marton and S. H. Lachenbruch, J. Research NBS **43**, (Oct. 1949) RP2033. See also, Electron optical mapping of electro-magnetic fields, by L. Marton and S. H. Lachenbruch, scheduled for publication in J. Applied Phys. **20**, (Nov. 1949).

[4] In the Schlieren method, a magnetic lens forms an image of a source of electrons on a small copper stop that intercepts all direct rays. If in the space between the electron source and the lens there is a variation of the index of refraction for electrons—in other words, a variation in electric or magnetic field intensity—an image of that inhomogeneity will then be produced by means of the same lens in a conjugate plane beyond the stop. Thus a dark-field image of the magnetic or electric field is obtained on a fluorescent screen or on a photographic plate. See Electron-optical Schlieren effect, NBS Technical News Bulletin **32**, 82 (1948).

ıadow Method

ides a valuable new tool for the quantitative study of elec-
ethod is illustrated in a simple manner by an analogous
ı (left) converges light from a distant source to form a
). A magnified shadow image of the wire screen is then
lower half of the light beam is intercepted by a piece of
some of the light rays, the result is a distortion of the
e electron-optical shadow method, the glass lens system is
rossover point (above). If a magnetic field is introduced
low), deflection of the electron beam by the field causes a
low network on the photographic plate. (D) The electron
as they pass through the field of a small horseshoe magnet
ire is the electron shadow of a fine wire mesh placed just
and reduced magnification of a selected part of the mesh,
point in the field can be accurately computed.



of the electron source. This displaced image, acting as a virtual source, forms a shadow image, likewise displaced, of the network. Deflection of the beam may also change the distance of the virtual source from the wire, in which case the magnification of the displaced image is affected. Obviously, the displacement and change in size of the shadow image at any point depend on the strength of the field of the magnetized wire at a corresponding point.

Formulas have been derived by S. H. Lachenbruch of the Bureau staff that permit the calculation of consistent absolute values of field strength in magnetic or electric fields of various geometrics from experimental measurements of the position of the wire mesh, the displacement and magnification of its shadow image, and the known constants of the apparatus. The patterns obtained also provide a qualitative visual representation of minute electrostatic and magnetic fields. Although it is possible to compute field intensity from the intensity distribution of the pattern obtained by the Schlieren method, the shadow method is of far greater utility for quantitative work, since the image displacement and magnification can be measured much more accurately than can the intensity distribution across the Schlieren pattern on a photographic plate.

Applications

Perhaps the greatest value of the electron-optical shadow method lies in its utility for exploring complex electric and magnetic fields of extremely small dimensions or in which a probe of size greater than the electron would disturb the field under study. In the past, calculations of the field intensity at a point have been limited to those special cases in which the geometry of the field exhibits a high degree of symmetry. The shadow technique now provides data for accurate calculation of the absolute value of the intensity in the neighborhood of a specimen of any size or shape without altering or disturbing the field.

The method is thus well adapted to investigation of the fundamental nature of ferromagnetism. Experiments now under way at this Bureau include a study of the behavior of the fringe fields of the ferro-magnetic domains; in this work a single crystal of cobalt having very large magnetic domains is being used. An extension to ferroelectric materials is also contemplated for the purpose of checking the domain theory of these substances; of particular interest will be a study of the polarization of barium titanate and other high-dielectric materials that are now being widely used in the production of small-sized capacitors for radio, radar, and television.

In another application of the shadow method at the Bureau, space-charge fields in several types of apparatus employing electron beams are being investigated. In this connection, use of the method with a pulsed electron source for the stroboscopic study of fields that vary with time is under study.

It has been suggested that the electron-optical shadow method may also be of value for the calculation of field intensities within a waveguide. Use of waveguides as conductors and circuit elements in ultra-high-frequency

radar and communication often leads to arrangements whose geometry is too complicated for expression in any system of mathematical coordinates. Thus the electronics engineer, having in many cases only an intuitive picture of the field distribution at junctions and elbows of the guide, must rely on empirical methods in designing waveguide techniques and equipment. By the use of suitable auxiliary techniques, it is hoped that the shadow method may be adapted to the calculation of field intensities in regions of a guide that are not at present susceptible to analytical treatment.

The Bureau is also applying the principle of the shadow technique to the study of spherical aberration in electron lenses. When a fine wire mesh is placed in the focal region of a lens having spherical aberration, the shadow image of the network is enlarged either centrally or at the periphery, depending on the position of the mesh and the nature of the lens error. The resultant pattern may thus be interpreted to give information of value in correcting the lens.

Effect of Simulated Service Conditions on Plastics

The use of laminated plastics in aircraft has increased during the past few years, especially in accessories and semistructural parts, such as bulkheads, partitions, linings, propellers, wing flaps, and ducts. There has accordingly developed a need for more comprehensive information regarding the action of the weather, temperature, and humidity on the properties of laminated plastics in order to evaluate these materials for aircraft application and to prepare specifications for suitable materials. To provide the necessary data, the Bureau carried out an investigation, under the sponsorship of the National Advisory Committee for Aeronautics, to determine the effects of outdoor weathering, accelerated weathering, and accelerated service conditions on the weight, dimensions, and flexural properties of representative phenolic and unsaturated-polyester plastics.[5] For accelerated weather testing the specimens were subject to cycles of ultraviolet light and fog, whereas the accelerated service tests consisted of cyclic exposure to various temperatures and relative humidities. The test materials were commercial products, and included nine laminated plastics and a macerated-fabric-filled phenolic plastic, which are the types commonly employed in aircraft.

Description of tested laminated plastics

Type of laminate	Average thickness	Density	No. of plies
	in.	*g/cm³*	
Glass-fabric, unsaturated polyester	0.116	1.70	7
Grade AA phenolic (asbestos fabric reinforced)	.149	1.50	5
High-strength-paper phenolic	.121	1.43	------
Grade L phenolic (cotton fabric reinforced)	.125	1.34	19
High-strength-paper, phenolic	.124	1.43	------
Muslin-cotton-fabric, unsaturated polyester	.131	1.27	7
Grade C phenolic (cotton fabric reinforced)	.122	1.36	7
Enameled-duck-cotton-fabric, unsaturated polyester	.145	1.37	6
Lignin paper [a]	.128	1.38	------
Macerated-cotton fabric phenolic molding compound [b]	.121	1.37	------

[a] Included to serve as a control on the severity of the tests because of the known dimensional instability of this type of plastic.

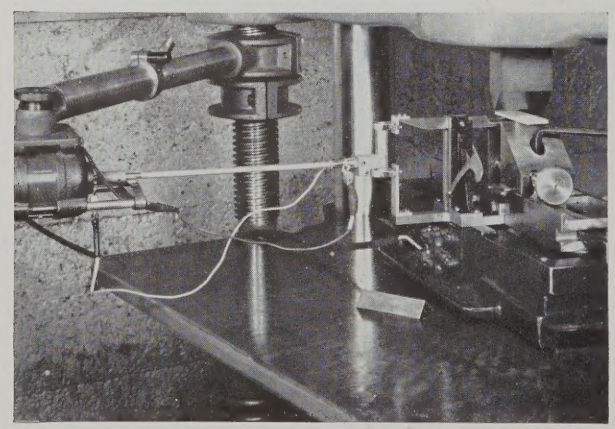
[b] Test specimen was in sheet form prepared from a molding compound; all other materials were laminated sheet products.

Three sets of specimens, mounted on racks at an angle of 45° facing south, were exposed for 1 year to outdoor weathering on the roof of the Industrial Building, National Bureau of Standards. The flexural properties were determined for one set, and weight and dimensions on a second set. The second and third sets were returned to the roof for another year's exposure. At the end of the second year the weight and dimensions and the flexural properties were determined on these specimens.

In the accelerated weathering test of alternate exposures to ultraviolet light and misty atmosphere, one set of specimens was used to measure weight and dimensions. From a second set flexural properties were determined after exposure to simulated conditions for 120, 240, 360, and 480 hours, respectively.

The six accelerated service tests involved exposure to cycles of temperatures from 70° to 175° F, relative humidities from 5 to 100 percent, and ultraviolet radiation. In each of the six tests the weight and dimensions of one set of specimens were measured after the conclusion of 1, 3, 5, and 10 cycles. The flexural properties were determined on other sets at the end of 5 and 10 cycles.

[5] For further technical details, see Effect of simulated service conditions on plastics, by W. A. Crouse, D. C. Caudill, and F. W. Reinhart, NACA Tech. Note No. 1240 (July 1947); also NACA Tech. Note No. 1738 (May 1948).



An adjustable-span flexural jig and extensometer (left) are used in conjunction with a hydraulic universal testing machine, to measure the flexural strength of laminated plastics as used in aircraft. The tests are part of a comprehensive investigation of the effects of weathering, temperature, and humidity on the properties of these plastics.

Changes in weight and dimensions and in flexural properties were the criteria used in analyzing the data gained during the investigations. In most of the tests the changes in weight and dimensions were negative, any positive changes being in thickness. The flexural tests revealed several cases in which increases in flexural strength resulted from the accelerated weathering and service conditions. These increases in strength were attributed to further cure of the resins.

Results of the laboratory aging tests did not in all cases correlate with the results of outdoor weathering. A laboratory evaluation procedure for material or groups of materials must therefore be selected on the basis of the materials, the properties to be determined, and the conditions which the materials will meet in service.

An accelerated service test consisting of alternate exposure for 24 hours at 175° F and 95- to 100-percent relative humidity, followed by 24 hours at 175° F and a relative humidity less than 5 percent, was the most severe of those used in this investigation. All the materials except the asbestos-fabric phenolic laminate increased in thickness in this test. This material was the only one that increased in flexural strength and flexural modulus of elasticity on exposure to the above accelerated service test.

The asbestos-fabric phenolic and glass-fabric unsaturated-polyester laminates were the most resistant of the materials tested. The paper-base phenolic laminates were not so stable in weight and thickness after outdoor weathering as the other materials tested. These results indicate that the most resistant laminates are those made with materials that are least affected by water.

Improvement of Laboratory Gas Burners

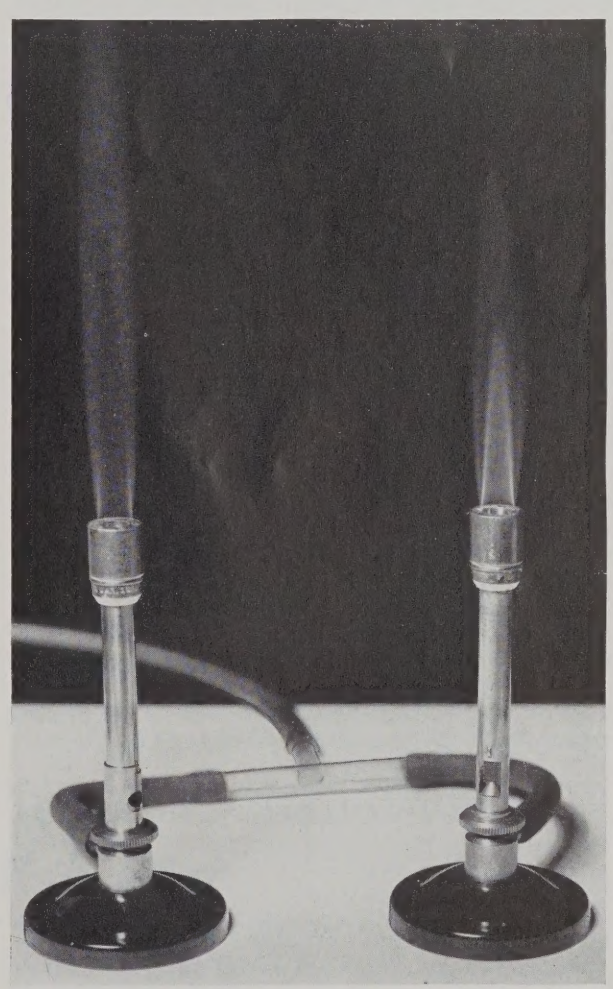
The flame characteristics of natural gas are so different from those of manufactured fuel gases that a change in supply from manufactured to natural gas necessitates the alteration of all gas-burning appliances. The different requirements of Bunsen and similar types of laboratory burners when they are used with natural gas have usually been overlooked by manufacturers. Even those burners advertised as designed for natural gas have not proved satisfactory.

As a result of this difficulty the National Bureau of Standards secured and tested sixteen different laboratory-type Bunsen burners, eight of which were of the Meker type and eight, straight-tube burners. The limits of operation of each of these burners, sold as suitable for natural gas, were determined. By a correlation of these data with the basic requirements for good burner design, the reasons for the poor showing on natural gas and the changes required for satisfactory operation were found.[6]

A survey of the various heating operations for which a laboratory burner is used indicated that the Meker-type burner should be capable of producing a hot, stable flame at gas rates up to 10,000 Btu per hour, and the straight-tube burners should be usable at rates up to 5,000 Btu per hour. The average maximum usable rate for the Meker burners tested was only 6,363 Btu per hour, while that for the straight tube burners was 2,781.

A comparison of the dimensions of the 16 burners with the fundamental relations for good burner operation brought out three major reasons for their unsatisfactory performance on natural gas.

(1) *Too small port area.* A Meker burner should have at least 1 square inch of free port area in order to deliver as much as 10,000 Btu per hour; only two of the eight Meker burners examined had ports as large as 1 square inch. From the results obtained on the straight-tube burners a port area of at least 0.15 square



Laboratory type gas burners give greatly improved performance with natural gas, when modified to meet basic requirements as determined at the Bureau (right). Both burners are adjusted so that gas is being burned at a rate of 5,000 Btu/hr.

[6] For further technical details, see A Study of laboratory Bunsen burners for natural gas, by John H. Eiseman, J. Research NBS **42**, 541 (1949), RP1991.

inch should be provided if rates up to 5,000 Btu per hour are desired. Only one of the straight-tube burners had a port as large as 0.15 square inch.

(2) *Improper throat size.* Results both from this study and those conducted by other investigators show the need of a throat with an area equal to 40 percent of the port area if optimum air entrainment is to be obtained. Most of the burners were unable to inject enough air to give a satisfactory flame with an orifice of adequate capacity. Only three of the Meker burners had throats close enough to the 40-percent requirement to approach optimum conditions.

(3) *Insufficient primary air opening.* Results showed a need for an air opening equal to at least 2.25 times the port area in order to insure sufficient primary air. A burner may be designed with a large enough port area and the proper venturi throat to inject a high percentage of primary air but may be prevented from doing so because of too small an opening for the air to enter the mixing tube. Of the sixteen burners only five had a ratio of air-shutter opening to port area as large as 2.25.

In addition to these three factors, use of the proper orifice size is equally important. The orifice size should be such as to give the maximum desired gas rate when used in its wide-open position, and the needle should be used only to reduce the rate below this maximum.

Fortunately, most of the changes required in these burners are not difficult to make. Two burners, one a straight-tube and the other a Meker type, were modified in Bureau shops so that they complied with the requirements outlined above. These burners were then retested and found to be greatly improved. The Meker burner gave a hot, stable flame at all rates up to 10,000 Btu per hour, and the straight tube burner could be satisfactorily used at rates up to 5,000 Btu per hour. The modified Meker burner was also used for a number of laboratory heating applications that required intense heat, for example, sodium carbonate fusion. It performed all of these operations satisfactorily.

The results, together with a demonstration of redesigned burners, were presented recently to a group of interested manufacturers. As a result of this meeting several manufacturers are redesigning their burners.

Celsius Versus Centigrade

The Ninth General Conference on Weights and Measures, held in October 1948, adopted the name "Celsius" for the scale of temperature that has more commonly been called "Centigrade". This action, which had not been proposed in advance of the Conference, arose from a question regarding preferred usage in French, the sole official language of the Conference. The decision therefore may be considered as applying strictly only to that language. In the interest of eventual uniformity of practice the use of Celsius appears desirable, but it is not practicable to impose this term on those who prefer Centigrade.

In preparation for the General Conference, the National Bureau of Standards submitted a revised text defining the International Temperature Scale to supersede that adopted in 1927. The proposed text was drafted in English, and, in accordance with common English practices as well as the official French text adopted in 1927, it used the name Centigrade. This name was carried over into the French translation prepared for consideration by the Advisory Committee on Thermometry in May 1948. However, in the printed report of that meeting, the term Centigrade had, in most cases, been changed to Centésimale, the term that is used in the French law governing weights and measures. When asked to choose between the two, the International Committee on Weights and Measures and the General Conference voted to substitute Celsius.

With regard to the merits of the decision it may be remarked that Celsius (abbreviated C) is analogous to the names Kelvin, Fahrenheit, Reaumur, and Rankine used for other temperature scales, that it has previously been used considerably in some countries, and occasionally in America, being included in Webster's dictionary. It might also be argued that Centigrade is logically ambiguous, since the absolute Kelvin scale, as well as the Centigrade scale, has 100 degrees between the ice point and the boiling point of water. On the other hand, the name Centigrade is thoroughly established in English-speaking countries, the need for choosing between that name and Centésimale arises only in French, and the decision on a term in the official French language of the Conference may not be considered as controlling the terms to be used in translating into other tongues.

Thirty-fourth National Conference on Weights and Measures

An all-time high in the number of weights and measures officials in attendance highlighted the Thirty-fourth National Conference on Weights and Measures, one of the most successful meetings in the history of this organization. The total registration for the Conference, sponsored by the National Bureau of Standards and held in Washington from May 24 to 27, was 292, including officials from 34 States, the District of Columbia, Federal, and local governments.

The Conference was opened by its President, Dr. E. U. Condon, Director of the National Bureau of Standards. Dr. Condon commented upon the expanded program of cooperation between the Bureau's Office of Weights and Measures and State and local

weights and measures officials throughout the country, carried on through the medium of attendance at State and regional conferences, as well as voluntary visits to weights and measures offices. He also reviewed the developments since the Thirty-third National Conference in the field of State weights and measures legislation and reported numerous changes in the weights and measures personnel of the States that have occurred during this interval.

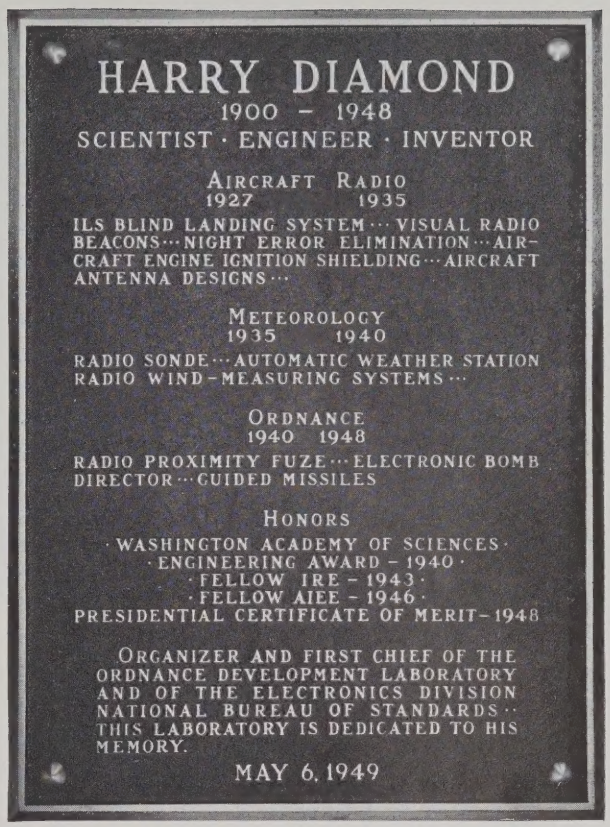
The major technical action of the Conference was the adoption of a general revision of the specifications, tolerances, and regulations for commercial weighing and measuring devices, as proposed by the Committee on Specifications and Tolerances. The principal purposes of the revision are to unify the arrangement of the codes; to provide a uniform system of paragraph identification; to shorten the text wherever practicable; and to simplify the language with the view of making the requirements more understandable and thus promoting uniformity and consistency of enforcement by State and local regulatory officials. In general, basic requirements for the several classes of commercial equipment remain unchanged.

For many years the National Conference codes have carried certain requirements as "nonretroactive," that is, as applicable only to new devices brought into a jurisdiction after promulgation of the codes. In the present revision, however, the amount of nonretroactive material has been sharply reduced, because it was felt that it is no longer necessary for much of this material to be restricted in its application to new devices, even in jurisdictions initially promulgating the codes. Another feature is the establishment of a "general code," in which are assembled those requirements which, in general, apply to all classes of commercial weighing and measuring devices. The revision is now available as NBS Handbook H44.[7]

The report of the Committee on Legislation recommended reiteration of the Conference endorsement of the principle of food package standardization; recognition of the desirability of legislation to provide maximum protection to all parties concerned in the matter of proper repairing and servicing of weighing and measuring devices; and the development of model legislation covering public weighmasters for incorporation in the model law on weights and measures of the National Conference. The Conference granted an extension of authority to this Committee to include drafting of legislation to be presented to the Conference.

The report of the Committee on Weights and Measures Education stressed the desirability of "self education" on the part of weights and measures officials. The report noted, as typical of educational programs being conducted by weights and measures jurisdictions, the "Betty Budget" program developed in Chicago; the Detroit program of visual education utilizing a carefully chosen set of color slides; and a 15-minute sound motion picture entitled "Getting Your Money's Worth," prepared under the sponsorship of the Virginia Weights and Measures Association.

7 Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $1.00 a copy.


HARRY DIAMOND
1900 - 1948
SCIENTIST · ENGINEER · INVENTOR
AIRCRAFT RADIO
1927 1935
ILS BLIND LANDING SYSTEM··· VISUAL RADIO BEACONS··· NIGHT ERROR ELIMINATION··· AIRCRAFT ENGINE IGNITION SHIELDING··· AIRCRAFT ANTENNA DESIGNS···
METEOROLOGY
1935 1940
RADIO SONDE··· AUTOMATIC WEATHER STATION RADIO WIND-MEASURING SYSTEMS···
ORDNANCE
1940 1948
RADIO PROXIMITY FUZE··· ELECTRONIC BOMB DIRECTOR··· GUIDED MISSILES
HONORS
· WASHINGTON ACADEMY OF SCIENCES ·
· ENGINEERING AWARD - 1940 ·
· FELLOW IRE - 1943 ·
· FELLOW AIEE - 1946 ·
PRESIDENTIAL CERTIFICATE OF MERIT - 1948
ORGANIZER AND FIRST CHIEF OF THE ORDNANCE DEVELOPMENT LABORATORY AND OF THE ELECTRONICS DIVISION NATIONAL BUREAU OF STANDARDS·· THIS LABORATORY IS DEDICATED TO HIS MEMORY.
MAY 6, 1949

HARRY DIAMOND ORDNANCE LABORATORY

The ordnance laboratory of the National Bureau of Standards was dedicated on May 6, 1949, to the memory of the late Harry Diamond, who was the first chief of the Bureau's Electronics Division. The memorial plaque listing Mr. Diamond's most notable contributions to science was unveiled at that time in the conference room of the laboratory. The Harry Diamond Ordnance Laboratory, which was erected in 1945, serves as a developmental laboratory for the Ordnance Departments of the National Military Establishment.

The report of the Committee on Methods of Sale of Commodities included recommendations that the amount of solids and amount of liquids be separately declared in the quantity marking of packaged frozen foods; and that a standard of measure for roofing be established on the basis of coverage in terms of the "square foot" or the "Square," the latter being an area equal to 100 square feet. Other recommendations of this Committee covered thread, facial tissues, bar soaps, commodities of variable weights in packaged form, and wiping cloths. The Committee on Trading by Weight noted the assistance given in promoting the general practice of trading in grains by weight and recommended continuing support of this program.

Reports were presented from 28 states and the District of Columbia as well as 13 weights and measures associations. The formal program comprised, in addition to reports, 22 topics and listed 26 speakers.

Proceedings, Technical Session on Bone Char

The First Technical Session on Bone Char Research was held at the National Bureau of Standards on January 27 and 28, 1949, under the sponsorship of the Bureau and those industries supporting bone char research. The proceedings of the Session have now been published and are available from the Bone Char Research Project, Inc.

The purpose of the Session was to offer representatives of the sugar refineries and bone char manufacturers an opportunity to learn the status of the fundamental research program on bone char and other solid adsorbents. The Session was divided into four half-day meetings devoted to the following subjects: Bone char kilns, test procedures, filtration operations, and basic research on the properties of bone char. The 14 formal papers that were presented are printed in full, together with the discussions that followed each paper.

Proceedings of the Technical Session on Bone Char, 1949, 321 large-size pages adequately illustrated with figures, charts, and halftones, is available at $2.00 a copy from J. M. Brown, Secretary-Treasurer, Bone Char Research Project, Inc., c/o Revere Sugar Refinery, 333 Medford Street, Charlestown 29, Mass.

NBS Publications

Periodicals [8]

Journal of Research of the National Bureau of Standards, volume 43, number 2, August 1949. (RP2010 to RP2019, inclusive).

Technical News Bulletin, volume 33, number 8, August 1949. 10 cents.

CRPL–D59. Basic Radio Propagation Predictions for November 1949. Three months in advance. Issued August 1949. 10 cents.

Nonperiodical

Research Papers [8 9]

RP2000. Volume changes observed in small concrete cylinders during freezing and thawing with a mercury displacement dilatometer. Rudolph C. Valore. 20 cents.

RP2001. Electrophoresis of modified collagen. James M. Cassel and Joseph R. Kanagy. 10 cents.

RP2002. Infrared absorption spectra of cyclohydrocarbons. Earle K. Plyler and Nicola Acquista. 10 cents.

RP2003. Low-temperature performance of radiosonde electric hygrometer elements. Arnold Wexler. 10 cents.

RP2004. Refractive index of natural rubber for different wavelengths. Lawrence A. Wood and Leroy W. Tilton. 10 cents.

RP2005. Metastable transitions in mass spectra of hydrocarbons. Evelyn G. Bloom, Fred L. Mohler, C. Edward Wise, and Edmund J. Wells. 10 cents.

RP2006. Impedance characteristics of some experimental broad-band antennas for vertical incidence ionosphere sounding. H. N. Cones. 10 cents.

RP2007. Formulas for the percentage points of the distribution of the arithmetic mean in random samples from certain symmetrical universes. Utam Chand. 10 cents.

RP2008. Refractive indices of thallium bromide-iodide crystals for visible and infrared radiant energy. Leroy W. Tilton, Earle K. Plyler, and Robert E. Stephens. 10 cents.

RP2009. Fundamental aspects of the reaction of oxygen with carbon adsorbents. William V. Loebenstein and Neil L. Pennington. 10 cents.

Circulars [8]

C475. Establishment and maintenance of the electrical units. F. B. Silsbee. 25 cents.

Miscellaneous [8]

M193. Laboratory and service tests of hand luggage. Edward T. Steiner, Robert B. Hobbs, and Elizabeth R. Hosterman. 15 cents.

M194. Research and development in applied optics and optical glass at the National Bureau of Standards. Irvine C. Gardner and C. H. Hahner. 15 cents.

Simplified Practice Recommendations [8]

R133–49. Surgical dressings. (Supersedes R133–47.) 10 cents.

Articles by Bureau Staff Members in Outside Publications [10]

Deficiencies of tinfoil substitutes in the processing of acrylic resins. George W. Ferguson, George C. Paffenbarger, and Irl C. Schoonover. J. Am. Dental Assn. (222 East Superior Street, Chicago, Ill.) **38,** 573 (1949).

Interaction of polymers and vapors. John W. Rowan and Robert Simha. J. Phys. and Colloid Chem. (Williams and Wilkins Co., Mt. Royal and Guilford Avenues, Baltimore 2, Md.) **53,** 921 (1949).

Fire-retardant coatings for fabric-covered aircraft. S. G. Weissberg, H. L. Hansberry, and G. M. Kline. Ind. and Eng. Chem. (1155 Sixteenth Street, NW, Washington 6, D. C.) **41,** 1742 (1949).

Stability test for additive-treated motor oils. S. A. McKee and Ann Fritz. Anal. Chem. (1155 Sixteenth Street, NW, Washington 6, D. C.) **21,** 568 (1949).

Investigations of galvanic cells with solid and molten electrolytes. Walter J. Hamer and John P. Schrodt. J. Am. Chem. Soc. (1155 Sixteenth Street, NW, Washington 6, D. C.) **71,** 2347 (1949).

A method for determining the extent of polymerization of acrylic resins and its applications for dentures. Harold J. Caul and Irl C. Schoonover. J. Am. Dental Assn. (222 East Superior Street, Chicago, Ill.) **39,** 1 (1949).

Characteristics of the material in the magnetic fluid clutch. Henry D. Saunderson. Proc. 5th Annual Meeting Metal Powder Assn. (420 Lexington Avenue, New York 17, N. Y.) p. 93 (1949).

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[8] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, $4.50 (foreign $5.50); Technical News Bulletin, $1.00 (foreign $1.35); Basic Radio Propagation Predictions, $1.00 (foreign $1.25). Single copy prices of publications are indicated in the lists.

[9] Reprints from July Journal of Research.

[10] These publications are not available from the Government. Requests should be sent direct to the publishers.

U. S. GOVERNMENT PRINTING OFFICE: 1949